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(54) Process for the production of ethylenic polymers

(57) A process for the production of ethylenic polymers is disclosed in which an ethylenic monomer is polymerized in the presence of a catalyst comprising a chromium compound, an alumoxane and an organometallic alkoxide and/or organoaluminum siloxide and a carrier supporting thereon these compounds. The resultant polymer has a balanced proportion of rigidity and environmental stress cracking resistance (ESCR) and an excellent moldability property.

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D scription

This invention relates to a process for the production of ethylenic polymers, more particularly such a process using a novel catalyst which will afford the resultant polymer with a balanced proportion of rigidity and environmental stress cracking resistance (ESCR) and an excellent moldability property.

Ethylenic polymers have hitherto found wide application as a resinous material to produce a variety of molded articles having different properties dependent upon the specific method of molding employed and the particular usage intended. For instance, suitable ethylenic polymers for injection molding are those which have a relatively low molecular weight and a relatively narrow molecular weight distribution. However, for the production of molded articles by inflation or blow molding, there may be suitably used polymers which are relatively high in molecular weight and relatively wide in molecular weight distribution.

Ethylenic polymers may be produced in the presence of a Phillips catalyst (with chromium trioxide carried on a support of silica or other inorganic oxides), such polymers having a relatively wide molecular weight distribution eligible for blow molding.

Alternatively, ethylenic polymers suitable for blow molding may be produced in the presence of Ziegler catalyst by a single- or multi-step polymerization as disclosed in Japanese Patent Laid-Open Publication Nos. 2-123108, 4-18407 and 5-230136.

However, blow-molded articles from the above ethylenic polymers of relatively wide molecular weight distribution would have the following drawbacks:

1. Inadequate balance of rigidity and ESCR.
2. Insufficient melt tension, lending to irregularities in blown thickness and coarse surface finish.

Japanese Patent Laid-Open Publication No. 7-503739 discloses a method for the production of ethylenic polymers having a wide molecular weight distribution in the presence of a catalyst comprising chromium compounds and alumoxane. However, the resulting ethylenic polymers are not sufficient in balance of rigidity and ESCR and melt tension.

Further alternatively, there has been used a catalyst comprising a solid catalyst component with chromium trioxide supported on a carrier of inorganic oxides, alumoxane, organoaluminum alkoxide or organoaluminum siloxide thereby obtaining ethylenic polymers having a wide molecular weight distribution as disclosed in Japanese Patent Laid-Open Publication Nos. 2-105806 and 2-185506.

Japanese Patent Laid-Open Publication No. 54-120290 discloses the use of catalyst comprising alumoxane and a solid component with an ester of chromic acid supported on a silica and thereafter treated with an organoaluminum alkoxide. However, the ethylene polymers produced by the foregoing processes fail to reach a desired level of the balance of rigidity and ESCR and proper melt tension.

The present invention seeks to provide an improved process for the production of ethylenic polymers which will make available such polymers at increased rate of yield which have a well balanced proportion of rigidity and environmental stress cracking resistance (ESCR) and which are moldable to a desired specification.

It has now been found that the foregoing features of the invention can be attained by the process which is carried out in the presence of a catalyst comprising a chromium component, an alumoxane component and an organometallic alkoxide and/or organoaluminum siloxide.

According to the invention, there is provided a process for the production of ethylenic polymers which comprises polymerizing an ethylenic monomer in the presence of a catalyst comprising a chromium component (a) selected from the group consisting of a salt of carboxylic acid, a chromium-1,3-diketo compound, a chromium amide compound and an ester of chromic acid, an alumoxane component (b), an organometallic alkoxide and/or organoaluminum siloxide and a carrier supporting thereon these components.

In the inventive process, there are used two types of catalysts (I and II). The catalyst I comprises a chromium component (a) selected from the group consisting of a salt of carboxylic acid, a chromium-1,3-diketo compound and a chromium amide compound, an alumoxane component (b) and an organometallic component (c) selected from the group consisting of an organoaluminum alkoxide, an organoaluminum siloxide, an organomagnesium alkoxide and an organoboron alkoxide. The catalyst II comprises a chromium component (a) comprising an ester of chromic acid, an alumoxane component (b) and an organometallic component (c) selected from the group consisting of an organomagnesium alkoxide and an organoboron alkoxide.

The carrier for the catalysts I and II comprises an inorganic metal oxide or an inorganic metal halide. The carrier has a specific surface area of 50-1,000 m^2/g, a pore volume of 0.5-3.0 cm^3/g and an average particle size of 10-200 μm.

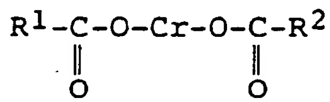
The catalysts I and II are prepared by supporting on the carrier with the chromium component (a), the alumoxane component (b) and the organometallic component (c) in this order or an order of (a), (c) and (b).

The catalysts I and II contain the chromium compound (a) in the range of 0.05-5.0 percent by weight as the amount of Cr based on the weight of the carrier and has an atomic ratio of aluminum in the alumoxane (b) to chromium in the

chromium compound (a) in the range of 0.5-100, an atomic ratio of B, Mg or Al in organometallic alkoxide and/or organometallic siloxide (c) to chromium in the chromium compound (a) in the range of 0.5-100 and a molar ratio of the alumoxane (b) to the organometallic alkoxide and/or organoaluminum siloxide (c) in the range of 0.01-100.

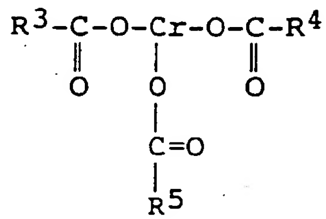
The invention will be further described in detail.

The chromium component (a) (except chromium oxide) referred to herein as one of the catalyst components of the invention exemplarily includes chromium salts of carboxylic acid, chromium-1,3-diketo compounds, chromium amide compounds and esters of chromic acid. Typical examples of the chromium salt of carboxylic acid are chromium (II) compounds or chromium (III) compounds represented by the following formulae (1) and (2):



..... (1)

and



..... (2)

wherein R^1, R^2, R^3, R^4 and R^5 each are hydrogen or a C_1-C_{18} hydrocarbon group which may be the same or different.

Specific examples include chromium (II) formate, chromium (II) acetate, chromium (II) propionate, chromium (II) butyrate, chromium (II) pentanoate, chromium (II) hexanoate, chromium (II) 2-ethylhexanoate, chromium (II) benzoate, chromium (II) naphthenate, chromium (II) oleate, chromium (II) oxalate, chromium (III) formate, chromium (III) acetate, chromium (III) propionate, chromium (III) butyrate, chromium (III) pentanoate, chromium (III) hexanoate, chromium (III) 2-ethylhexanoate, chromium (III) benzoate, chromium (III) naphthenate, chromium (III) oleate, chromium (III) oxalate, among which chromium (II) acetate, chromium (II) 2-ethylhexanoate, chromium (III) acetate, chromium (III) 2-ethylhexanoate are particularly preferred.

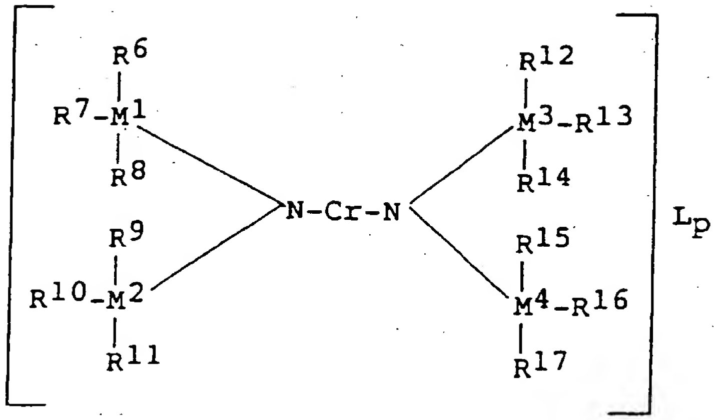
Typical examples of the chromium-1,3-diketo compound are chromium (III) complex having one or three 1,3-diketo compounds represented by the formula

$$CrX_kY_mZ_n \tag{3}$$

wherein X is a 1,3-diketo type chelate ligand, Y and Z are chosen from the group consisting of halogen, alkoxy, aryloxy, alkyl, aryl and amide, which may be the same or different, k + m + n is equal to 3 and k is $1 \le k \le 3$.

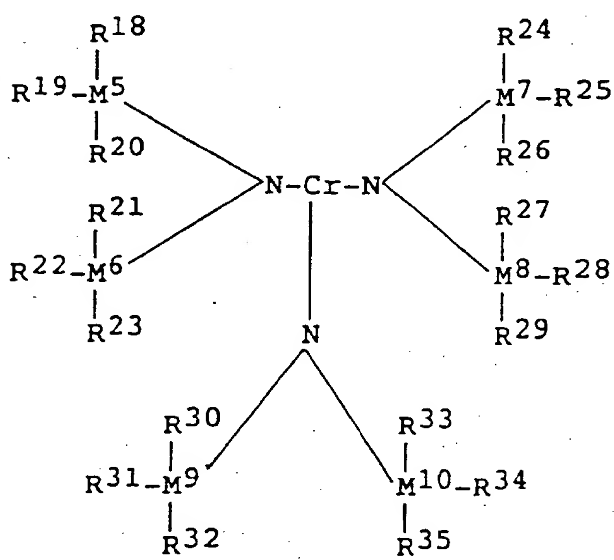
Specific examples include chromium-1,3-butanedionate, chromium acetylacetonate, chromium-2,4-hexanedionate, chromium-2,4-heptanedionate, chromium-2,4-octanedionate, chromium-3,5-octanedionate, chromium benzoylacetonate, chromium-1,3-diphenyl-1,3-propanedionate, chromium-2-methyl-1,3-butanedionate, chromium-2-ethyl-1,3-butanedionate, chromium-2-phenyl-1,3-butanedionate, chromium-1,2,3-triphenyl-1,3-propanedionate, among which chromium acetylacetonate is preferred.

Typical examples of the chromium amide compound are chromium (II) compound and chromium (III) compound represented by the formulae (4) and (5):



..... (4)

wherein R^6, R^7, R^8, R^9, R^{10}, R^{11}, R^{12}, R^{13}, R^{14}, R^{15}, R^{16} and R^{17} each are hydrogen or a C_1-C_{18} hydrocarbon group which may be the same or different, M^1, M^2, M^3 and M^4 are carbon and/or silicon, L is a ligand such as ether and nitryl and p is $0 \leq p \leq 2$: and



..... (5)

wherein R^{18}, R^{19}, R^{20}, R^{21}, R^{22}, R^{23}, R^{24}, R^{25}, R^{26}, R^{27}, R^{28}, R^{29}, R^{30}, R^{31}, R^{32}, R^{33}, R^{34} and R^{35} each are hydrogen or a C_1-C_{18} hydrocarbon group which may be the same or different and M^5, M^6, M^7, M^8, M^9 and M^{10} are atoms of carbon and/or silicon.

Specific examples include bis(bistrimethylsilylamide)chromium (II)-THF complex, bis(bistrimethylsilylamide)chromium (II)-diethylether complex, bis(methyltrimethylsilylamide)chromium (II)-THF complex, bis(methyltrimethylsilylamide)chromium (II)-diethylether complex, bis(tert-butyltrimethylsilylamide)chromium (II)-THF complex, bis(tert-butyltrimethylsilylamide)chromium (II)-diethylether complex, bis(phenyltrimethylsilylamide)chromium (II)-THF complex, bis (phenyltrimethylsilylamide)chromium (II)-diethylether complex, tris(dimethylamide)chromium (III), tris(diethylamide) chromium (III), tris(diisopropylamide)chromium (III), tris(methylphenylamide)chromium (III), tris(diphenylamide)chromium (III), tris(bistrimethylsilylamide)chromium (III), tris(bistriethylsilylamide)chromium (III), tris(bistriphenylsilylamide) chromium (III), among which tris(bistrimethylsilylamide)chromium (III) is preferred.

Typical examples of the ester of chromic acid are chromium (VI) compound represented by the formula

$$R^{37}-\underset{R^{38}}{\overset{R^{36}}{M^{11}}}-O-\underset{O}{\overset{O}{Cr}}-O-\underset{R^{41}}{\overset{R^{39}}{M^{12}}}-R^{40} \qquad \cdots\cdots (6)$$

wherein R^{36}, R^{37}, R^{38}, R^{39}, R^{40} and R^{41} each are a C_1-C_{18} hydrocarbon group which may be the same or different and M^{11} and M^{12} each are a carbon atom or silicon atom.

In the case where M^{11} and M^{12} are carbon, specific examples include bis(tert-butyl)chromate, bis(1,1-dimethylpropyl)chromate, bis(2-phenyl-2-propyl)chromate, bis(1,1-diphenylethyl)chromate, bis(triphenylmethyl)chromate, bis(1,1,2,2-tetramethylpropyl)chromate and bis(1,1,2-trimethylpropyl)chromate, among which bis(tert-butyl)chromate is preferred.

In the case where M^{11} and M^{12} are silicon, specific examples include bis(trimethylsilyl)chromate, bis(triethylsilyl)chromate, bis(tributylsilyl)chromate, bis(triisopentylsilyl)chromate, bis(tri-2-ethylhexylsilyl)chromate, bis(tridecylsilyl)chromate, bis(tri(tetradecyl)silyl)chromate, bis(tribenzylsilyl)chromate, bis(triphenethylsilyl)chromate, bis(triphenylsilyl)chromate, bis(tritolylsilyl)chromate, bis(trixylylsilyl)chromate, bis(trinaphthylsilyl)chromate, bis(dimethylphenylsilyl)chromate, bis(diphenylmethylsilyl)chromate, bis(dimethylhexylsilyl)chromate, bis(dimethylisopropylsilyl)chromate, bis(tert-butyldimethylsilyl)chromate, bis(tri-tert-butylsilyl)chromate, bis(triethylphenylsilyl)chromate, bis(trimethylnaphthylsilyl)chromate, polydiphenylsilylchromate and polydiethylsilylchromate, among which bis(triphenylsilyl)chromate is preferred.

The structure of alumoxane and the method of making the same are fully described in the Polyhedron, 9,429-453 (1990), Ziegler Catalysts, G. Fink et al. (Eds) 57-82, Springer-Verlag (1995). Alumoxanes eligible for use in the invention may be represented by the following formulae (7) and (8):

$$R^{42}{}_2Al-(O-\underset{R^{42}}{Al})_q-R^{42} \qquad \cdots\cdots (7)$$

or

$$\boxed{(O-\underset{R^{42}}{Al})_{q+1}} \qquad \cdots\cdots (8)$$

where R^{42} is a hydrocarbon group such as methyl, ethyl, propyl, n-butyl and isobutyl, preferably methyl and isobutyl and q is an integer of 1-100, preferably greater than 4, more preferably greater than 8.

These compounds may be produced by any conventional methods in which for example trialkylaluminum is added to a solvent of inert hydrocarbon such as pentane, hexane, heptane, cyclohexane, decane, benzene and toluene which suspends salts having crystal water such as cupric sulfate hydrate, aluminum sulfate hydrate or the like.

Alternatively, there may be also used alumoxane represented by the following formulae (9) and (10):

$$R^{43}{}_2-Al-(O-\underset{R^{43}}{Al})_r(O-\underset{R^{44}}{Al})_s-R^{44} \qquad \cdots\cdots (9)$$

and

$$\boxed{(O\text{-}\underset{\displaystyle R^{43}}{\underset{|}{Al}})_r(O\text{-}\underset{\displaystyle R^{44}}{\underset{|}{Al}})_s} \quad \ldots\ldots \quad (10)$$

where R^{43} is a hydrocarbon group such as methyl, ethyl, propyl, n-butyl and isobutyl, among which methyl and isobutyl are preferred, R^{44} is selected from the group consisting of a hydrocarbon group such as methyl, ethyl, propyl, n-butyl and isobutyl, halogen such as chlorine and bromine, hydrogen and hydroxyl group, which may be the same but is different from R^{43}, r is an integer of 1-100, preferably greater than 3 and r + s is equal to 2-101, preferably greater than 6.

The alumoxane represented by the formula (9) or (10) may have $(O\text{-}Al(R^{43}))_r$ unit and $(O\text{-}Al(R^{44}))_s$ unit bonded in block, or at random regularly or irregularly. These alumoxanes may be produced in a similar manner for the production of the same of the above formulae (7) and (8) in which more than two kinds of trialkylaluminum may be used instead of one trialkylaluminum or more than one kind of dialkylaluminum monohalide or dialkylaluminum monohydride may be used.

The organometallic alkoxides and/or organoaluminum siloxides eligible for use in the invention is one selected from Group II or XIII compounds of the Periodic Table, the compound being represented by either one of the following formulae (11), (12), (13) and (14);

$$R^{45}{}_tAl(OR^{46})_{3-t} \qquad (11)$$

where R^{45} and R^{46} are a C_1-C_{18} hydrocarbon group which may be the same or different and t is an integer of 1 or 2;

$$R^{47}R^{48}R^{49}Si\text{-}O\text{-}AlR^{50}R^{51} \qquad (12)$$

wherein R^{47}, R^{48}, R^{49}, R^{50} and R^{51} are a C_1-C_{18} hydrocarbon group which may be the same or different;

$$R^{52}Mg(OR^{53}) \qquad (13)$$

wherein R^{52} and R^{53} are a C_1-C_{18} hydrocarbon group which may be the same or different; and

$$R^{54}{}_uB(OR^{55})_{3-u} \qquad (14)$$

wherein R^{54} and R^{55} are a C_1-C_{18} hydrocarbon group which may be the same or different and u is an integer of 1 or 2.

The organoaluminum alkoxide represented by the formula (11) exemplarily include dimethylaluminummethoxide, dimethylaluminumethoxide, dimethylaluminumisopropoxide, dimethylaluminum-n-butoxide, dimethylaluminumisobutoxide, diethylaluminumethoxide, diethylaluminumisopropoxide, diethylaluminum-n-butoxide, diethylaluminumisobutoxide, diisobutylaluminumethoxide, diisobutylaluminumisopropoxide, diisobutylaluminum-n-butoxide, diisobutylaluminumisobutoxide, di-n-hexylaluminumethoxide, di-n-hexylaluminumisopropoxide, di-n-hexylaluminumbutoxide, di-n-hexylaluminumisobutoxide, methylaluminumdimethoxide, methylaluminumdiethoxide, methylaluminumdiisopropoxide, methylaluminumdi-n-butoxide, methylaluminumdiisobutoxide, ethylaluminumdiethoxide, ethylaluminumdiisopropoxide, ethylaluminumdi-n-butoxide, ethylaluminumdiisobutoxide, isobutylaluminumdiethoxide, isobutylaluminumdiisopropoxide, isobutylaluminumdi-n-butoxide, isobutylaluminumdiisobutoxide, n-hexylaluminumdiethoxide, n-hexylaluminumdiisopropoxide, n-hexylaluminumdi-n-butoxide and n-hexylaluminumdiisobutoxide.

Amongest these compounds, preferred are monoalkoxides such as dimethylaluminummethoxide, dimethylaluminumethoxide, dimethylaluminumisopropoxide, dimethylaluminum-n-butoxide, dimethylaluminumisobutoxide, diethylaluminumethoxide, diethylaluminumisopropoxide, diethylaluminum-n-butoxide, diethylaluminumisobutoxide, diisobutylaluminumethoxide, diisobutylaluminumisopropoxide, diisobutylaluminum-n-butoxide, diisobutylaluminumisobutoxide, di-n-hexylaluminumethoxide, di-n-hexylaluminumisopropoxide, di-n-hexylaluminum-n-butoxide and di-n-hexylaluminumisobutoxide.

These compounds may be synthesized with ease by any conventional methods in which for example trialkylaluminum of the formula $R^{45}{}_3Al$ is reacted with alcohol of the formula $R^{46}OH$, or in which trialkylaluminum of the formula $R^{45}{}_3Al$ is subjected to exchange reaction with aluminumtrialkoxide of the formula $Al(OR^{46})_3$, the former reaction being preferred for the purpose of the invention.

The organoaluminum siloxides of the formula (12) exemplarily include trimethyldimethylsiloxyalane, trimethyldiethylsiloxyalane, trimethyldiisobutylsiloxyalane, trimethyl-di-n-hexylsiloxyalane, triethyldimethylsiloxyalane, triethyldiethylsiloxyalane, triethyldiisobutylsiloxyalane, triethyldi-n-hexylsiloxyalane, triphenyldimethylsiloxyalane, triphenyldiethylsiloxyalane, triphenyldiisobutylsiloxyalane and triphenyl-di-n-hexylsiloxyalane.

Amongest these compounds, preferred are trimethyldimethylsiloxyalane, trimethyldiethylsiloxyalane, trimethyldiisobutylsiloxyalane, trimethyl-di-n-hexylsiloxyalane, triethyldimethylsiloxyalane, triethyldiethylsiloxyalane, triethyldiisobutylsiloxyalane and triethyl-di-n-hexylsiloxyalane.

These compounds may be synthesized with ease by the following conventional methods:

1) reaction of a silanol compound of the formula $R^{47}R^{48}R^{49}Si\text{-}OH$ with an organoaluminum compound of the formula $R^{50}R^{51}RAl$;
2) reaction of cyclosiloxane with an organoaluminum compound of the formula $R^{50}R^{51}RAl$; and
3) reaction of polysiloxane with an organoaluminum compound of the formula $R^{50}R^{51}RAl$.

R^{47} through R^{51} of the above formulae are the same as those of the formula (12). R of the above formula is the same as either R^{47} through R^{51} and is the group which is substituted upon reaction.

The organomagnesium alkoxides represented by the formula (13) exemplarily include ethylmagnesiummethoxide, ethylmagnesiumethoxide, ethylmagnesiumisopropoxide, ethylmagnesium-n-butoxide, ethylmagnesiumisobutoxide, ethylmagnesiumphenoxide, butylmagnesiummethoxide, butylmagnesiumethoxide, butylmagnesiumisopropoxide, butylmagnesium-n-butoxide, butylmagnesiumisobutoxide and butylmagnesiumphenoxide, among which ethylmagnesiumethoxide, ethylmagnesiumisopropoxide, ethylmagnesium-n-butoxide and ethylmagnesiumisobutoxide are preferred.

These compounds may be synthesized with ease by any conventional methods in which for example dialkylmagnesium represented by the formula $R^{52}{}_2Mg$ is reacted with alcohol represented by the formula $R^{53}OH$.

The organoboron alkoxides represented by the formula (14) exemplarily include dimethylmethoxyborane, dimethylethoxyborane, dimethylpropoxyborane, dimethylbutoxyborane, diethylmethoxyborane, diethylethoxyborane, diethylpropoxyborane, diethylbutoxyborane, methyldimethoxyborane, methyldiethoxyborane, methyldipropoxyborane, methyldibutoxyborane, ethyldimethoxyborane, ethyldiethoxyborane, ethyldipropoxyborane, ethyldibutoxyborane, phenyldimethoxyborane, phenyldiethoxyborane, phenyldipropoxyborane, phenyldibutoxyborane, diphenylmethoxyborane, diphenylethoxyborane, diphenylpropoxyborane and diphenylbutoxyborane.

Amongst the compounds, preferred are dimethylmethoxyborane, dimethylethoxyborane, dimethylpropoxyborane, dimethylbutoxyborane, diethylmethoxyborane, diethylethoxyborane, diethylpropoxyborane and diethylbutoxyborane.

These compounds may be synthesized with ease by any conventional method such as by exchange reaction of Grignard reagent represented by the formula $R^{54}MgX$ wherein X is halogen or an organolithium reagent represented by the formula $R^{54}Li$ with ester of boric acid represented by $B(OR^{55})_3$.

The organometallic alkoxides and organoaluminum siloxides represented by the above formulae (11)-(14) may be used singly or in combination.

The catalyst used for the inventive process comprises a carrier such as inorganic oxide and inorganic halide supported thereon with the catalyst components. The carrier have a specific surface area of 50-1,000 m^2/g, preferably 200-800 m^2/g, a pore volume of 0.5-3.0 cm^3/g, preferably 1.0-2.5 cm^3/g and an average particle size of 10-200 μm, preferably 50-150 μm. Inorganic oxides eligible for the carrier exemplarily include the oxides of metals of Group II, IV, XIII or XIV in the Periodic Table such as magnesia, titania, zirconia, alumina, aluminum phosphate, silica, silica-titania, silica-zirconia, silica-alumina and mixtures thereof.

These inorganic oxides are preferably those which are calcined in fluid state through molecular sieves in the presence of sufficient dry nitrogen gas at 100°-900°C for 10 minutes to 24 hours.

Inorganic halides eligible for the carrier exemplarily include the halides of metal of Group II or XIII in the Periodic Table such as magnesium chloride, magnesium bromide, magnesium iodide, calcium chloride, aluminum chloride, gallium chloride and mixtures thereof.

The catalyst may be derived by a method in which a chromium component, an alumoxane component, an organometallic alkoxide and/or organoaluminum siloxide and a carrier are introduced into a reaction vessel. Preferably the carrier is supported thereon with the chromium component, followed by the addition of the alumoxane component, the organometallic alkoxide and/or organoaluminum siloxide. More preferably, the carrier is supported thereon with the chromium component, followed by the addition of the alumoxane component and then the organometallic alkoxide and/or organoaluminum siloxide.

Each of the catalyst components is preferably reacted in an inert hydrocarbon solvent including propane, butane, isobutane, pentane, hexane, heptane, cyclohexane, decane, benzene, toluene and xylene. The amount of the solvent used in optional. After the completion of reaction, the solvent can be removed in vacuum or separated by filtration. The chromium component should be supported in an amount of 0.05 to 5.0 percent by weight as the amount of Cr based on the weight of the carrier, preferably 0.05 to 2.0 percent by weight. The alumoxane component should be supported in an amount of 0.5 to 100, by an atomic ratio of aluminum to chromium.

The organometallic alkoxide and/or organoaluminum siloxide should supported in an amount of 0.5 to 100, by an atomic ratio of B, Mg or Al in organometallic alkoxide and/or organoaluminum siloxide to chromium.

The alumoxane and the organometallic alkoxide and/or organoaluminum siloxide are used in a molar ratio of 0.01 to 100.

The reaction temperature is in the range of from 0°C to boiling point of the solvent. The time length for the above treatment and reaction ranges from 5 minutes to 24 hours.

The inventive process may be carried out by applying the catalyst to liquid phase such as slurry and solution or gas-phase polymerization processes. Liquid phase polymerization processes may be usually conducted in a hydrocarbon solvent including inert hydrocarbon such as propane, butane, isobutane, hexane, cyclohexane, heptane, benzene, toluene and xylene which may be used singly or in combination.

Reaction temperature in the liquid or gas-phase polymerization may be at from 0 to 300°C, preferably 20 to 200°C. The molecular weight of a polymer to be formed can be controlled by feeding a predetermined amount of hydrogen into the reaction system. If necessary, copolymerization can be also conducted by feeding one or more of α-olefins such as propylene, 1-butene, 1-hexene, 4-methyl-1-pentene and 1-octene into the reaction system.

The invention will be further described by way of the following examples which are provided for purposes of illustration only.

The procedures of determining the physical properties of the polymers provided in the Inventive and Comparative Examples are identified as follows:

a) Pretreatment of polymers:

Kneaded by plastgraph (manufactured by Toyo Seiki Co.) with use of 0.2 wt% of an additive (B225, Chiba Geigy) in nitrogen atmosphere at 190°C for 7 minutes.

b) Molecular weight and its distribution:

Number-average molecular weight (Mn) and weight-average molecular weight (Mw) were measured by a gel permeation chromatograph (GPC). Molecular weight distribution is represented by the ratio of Mw/Mn and is wider the greater the Mw/Mn ratio. GPC measurement was made of a sample concentration 2 mg/5 ml with use of Waters 50C model with column of Shodex-HT 806M in the presence of 1,2,4-trichlorobenzene at 135°C subject to universal calibration using a monodisperse polystyrene fraction.

c) Melt flow rate:

The measurement of melt flow rate was conducted in accordance with condition 7 in Table 1 of JIS K-7210 at 190°C with a load of 21.6 kgf and indicated as HLMFR.

d) Density:

Density was measured in accordance with JIS K-7112.

e) Melt tension:

Melt tension was measured using a melt tension tester with an orifice having a diameter of 2.1 mm and a length of 8.0 mm at a temperature of 210°C, extruding at 15 mm/min and rolling at 6.5 m/min.

f) Rigidity:

Rigidity was represented by modulus in flexure measured in accordance with JIS K-7203.

g) Environmental stress cracking resistance (ESCR):

ESCR is F_{50} value measured by BTL method in accordance with JIS K-6760.

The results are shown in Table below.

Inventive Example 1

1) Synthesis of trimethyldiethylsiloxyalane

44.4 ml hexane solution containing triethylaluminum (Tosoh Akzo Co., Ltd.) in a concentration of 1.0 mol/l hexane was cooled to 0°-5°C and then added with droplets of 5.6 ml trimethylsilanol (50 mmol of Shinetsu Kagaku Co., Ltd.). The admixture was stirred at a temperature of 25°C for 30 minutes thereby providing hexane containing trimethyldiethylsiloxyalane in a concentration of 1.0 mol/l of hexane.

2) Preparation of catalyst

A 100 ml flask was purged with nitrogen and fed with 4.0 grams silica (specific surface area 320 m^2/g, pore

volume 2.0 cm^3/g, average particle size 40 μm, ES70 Grade of Crosfield Co., Ltd.) which had been calcined at 500°C for 6 hours, followed by addition of 40 ml n-hexane to provide a slurry. This slurry was added with 1.5 ml hexane solution containing chromium (III) 2-ethylhexanoate (STREM Co., Ltd.) in a concentration of 0.1 mol/l of hexane (0.2 wt% of Cr) and then stirred at a temperature of 25°C for 15 minutes. At the end of this period, the slurry was added with 1.5 ml hexane solution containing isobutylalumoxane (Tosoh Akzo Co., Ltd.) in a concentration of 1.0 mol/l of hexane and stirred at a temperature of 25°C for 30 minutes. The resulting admixture was added with 0.5 ml of the above hexane solution containing trimethyldiethylsiloxyalane in a concentration of 1.0 mol/l of hexane and stirred at a temperature of 25°C for 30 minutes, followed by removal of the solvent in vacuum to provide a catalyst comprising a carrier supporting thereon the catalyst components and having a free fluidity property.

3) Gas-phase polymerization

Gas-phase polymerization was carried out using a reaction vessel of vertical vibration type similar to a fluidized bed reactor (volume 150 cm^3, diameter 50 mm, vibrating rate 420 times/minutes (7 Hz), vibrating distance 6 cm) which is fully described in the Eur. Polym. J., Vol. 21, 245 (1985).

The reaction vessel purged with nitrogen was charged with 120 mg of the above catalyst sealed in nitrogen atmosphere into an ampul and heated to 85°C, followed by pressurizing with 14 kg/cm^2 of ethylene. The ampul was broken by vibrating the reaction vessel, whereupon the polymerization reaction was initiated and continued at a temperature of 89°C for 2 hours. Ethylene was supplied via a flexible joint to maintain the pressure in the reaction vessel. Upon completion of the polymerization reaction, the supply of ethylene was discontinued and the reaction vessel was cooled to room temperature, followed by removal of excess gas. The reaction product was taken out to provide 20 grams particulate white polyethylene.

Inventive Example 2

The procedure of Inventive Example 1 was followed except for the use of 0.5 ml hexane solution containing diethylaluminumethoxide (Tosoh Akzo Co., Ltd.) substituted for trimethyldiethylsiloxyalane in a concentration of 1.0 mol/l of hexane. There was obtained 22 grams polyethylene.

Inventive Example 3

The procedure of Inventive Example 1 was followed except that 1.5 ml toluene solution containing chromium acetylacetonate (Wako Junyaku Co., Ltd.) substituted for chromium (III) 2-ethylhexanoate in a concentration of 0.1 mol/l of toluene (0.2 wt% of Cr) was used and polymerization temperature was 82°C. There was obtained 18 grams polyethylene.

Inventive Example 4

The procedure of catalyst preparation of Inventive Example 1 was followed except for the use of 1.5 ml toluene solution containing chromium acetylacetonate (Wako Junyaku Co., Ltd.) in a concentration of 0.1 mol/l of toluene substituted for chromium (III) 2-ethylhexanoate (0.2 wt% of Cr) and 0.5 ml hexane solution of diethylaluminumethoxide (Tosoh Akzo Co., Ltd.) substituted for trimethyldiethylsiloxyalane in a concentration of 1.0 mol/l hexane. The polymerization procedure of Inventive Example 1 was also followed except that the polymerization temperature was 82°C. There was obtained 19 grams polyethylene.

Inventive Example 5

1) Synthesis of diethylethoxyborane and bis(tert-butyl)chromate

In accordance with the method described in Justus Liebigs Ann. Chem., 352 (1975), diethylethoxyborane was synthesized by reacting triethylborane with ethanol in the presence of a catalyst of N,N-diethylpivalylamide. In accordance with the method described in Synth. Commun., 10,905 (1980), bis(tert-butyl)chromate was synthesized by reaction of chromium trioxide with tert-butanol.

2) Preparation of catalyst and polymerization

The procedure of Inventive Example 1 was followed except for the use of 1.5 ml hexane solution containing the above bis(tert-butyl)chromate substituted for chromium (III) 2-ethylhexanoate in a concentration of 0.1 mol/l of hexane (0.2 wt% of Cr) and 0.5 ml hexane solution of the above diethylethoxyborane substituted for trimethyldiethylsiloxyalane in a concentration of 1.0 mol/l of hexane. The procedure of polymerization of Inventive Example 1 was followed except that the polymerization temperature was 85°C. There was obtained 30 grams polyethylene.

Inventive Example 6

1) Synthesis of chromium (III) tris(bistrimethylsilylamide)

In accordance with the method disclosed in J. Chem. Soc. (A), 1433 (1971), chromium (III) tris(bistrimethylsilylamide) was synthesized by reaction of anhydrous chromium trichloride with lithiumbistrimethylsilylamide.

2) Preparation of catalyst and polymerization

The procedure of Inventive Example 1 was followed except that 1.5 ml hexane solution containing the above chromium (III) tris(bistrimethylsilylamide) substituted for chromium (III) 2-ethylhexanoate in a concentration of 0.1 mol/l of hexane (0.2 wt% of Cr) was used and 1.5 ml toluene solution containing methylalumoxane (Tosoh Akzo Co., Ltd.) substituted for isobutylalumoxane in a concentration of 1.0 mol/l of toluene was used. The procedure of Inventive Example 1 was followed except that the polymerization temperature was 92°C. There was obtained 22 grams polyethylene.

Inventive Example 7

1) Synthesis of ethylmagnesiumethoxide

In accordance with the method described in J. Chem. Soc. (A), 1118 (1968), ethylmagnesiumethoxide was synthesized by reaction of diethylmagnesium with ethanol.

2) Preparation of catalyst and polymerization

The procedure of Inventive Example 1 was followed except for the use of 1.5 ml hexane solution containing chromium (III) tris(bistrimethylsilylamide) of Inventive Example 6 substituted for chromium (III) 2-ethylhexanoate in a concentration of 0.1 mol/l of hexane (0.2 wt% of Cr) and of 1.5 ml toluene solution containing methylalumoxane (Tosoh Akzo Co., Ltd.) substituted for isobutylalumoxane in a concentration of 1.0 mol/l of toluene and of 0.5 ml hexane solution containing the above ethylmagnesiumethoxide substituted for trimethyldiethylsiloxyalane in a concentration of 1.0 ml hexane. The fprocedure of polymerization of Inventive Example 1 was followed except that the polymerization temperature was 92°C. There was obtained 24 grams polyethylene.

Inventive Example 8

Preparation of catalyst and slurry polymerization

To prepare the catalyst, the procedure of Inventive Example 1 was followed except for the use of 1.5 ml hexane solution containing chromium (III) tris(bistrimethylsilylamide) synthesized in Inventive Example 6 in place of chromium (III) 2-ethylhexanoate in a concentration of 0.1 mol/l of hexane (0.2 wt% of Cr) and of 1.5 ml toluene solution containing methylalumoxane (Tosoh Akzo Co., Ltd.) substituted for isobutylalumoxane in a concentration of 1.0 mol/l of toluene thereby to obtain a catalyst having a free fluidity property.

A one-liter autoclave equipped with stirrer was purged with nitrogen and charged with 500 ml anhydrous n-hexane and 40 mg of the above catalyst.

The autoclave was heated up to a temperature of 93°C and pressurized with ethylene up to 28 kg/cm^2. The slurry polymerization was carried out with ethylene supplied to maintain this pressure. By external cooling, the polymerization temperature was maintained at a temperature of 95°C for one hour. At the end of this period, the ethylene feed was discontinued and the autoclave was cooled to a temperature of 70°C, followed by removal of excess gas. The reaction product was taken out to provide 84 grams particulate white polyethylene.

Comparative Example 1

The procedure of Inventive Example 1 was followed except that trimethyldiethylsiloxyalane was not used. There was obtained 18 grams of polyethylene. The resulting polyethylene was inferrior in balance of proportion in rigidity and ESCR to that of Inventive Example 1.

Comparative Example 2

The procedure of Inventive Example 3 was followed except that trimethyldiethylsiloxyalane was not used. There was obtained 15 grams of polyethylene. The resulting polyethylene was not well balanced in rigidity and ESCR and lower in melt tension as compared to that of Inventive Example 3.

Comparative Example 3

The procedure of Inventive Example 6 was followed except that trimethyldiethylsiloxyalane was not used. There was obtained 18 grams polyethylene. The resulting polyethylene was not well balanced in rigidity and ESCR and lower in melt tension as compared to Inventive Example 6.

Comparative Example 4

The procedure of Inventive Example 8 was followed except that the.polymerization reaction was carried out using 0.4 gram Phillips catalyst which comprises silica supporting thereon chromium trioxide (1.0 wt% of Cr) and had been calcined in the air at a temperature of 600°C for 30 hours, in place of the inventive catalyst comprising a chromium component, an alumoxane component, organometallic alkoxide and/or organoaluminum siloxide and that the polymerization temperature was 102°C. The Phillips catalyst is available from W.R. Grace Corporation as 969ID. There was obtained 120 grams polyethylene. The resulting polyethylene was not well balanced in rigidity and ESCR and lower in melt tension as compared to Inventive Examples 1 through 8.

Comparative Example 5

1) Preparation of catalyst

30 grams noncalcined silica (ES70 Grade of Crosfield Co., Ltd.) was impregnated into a solution of chromium trioxide to be supported with a chromium in an amount of 0.20 wt%, followed by evaporation of water and calcination at a temperature of 600°C for 30 hours. A 100 ml flask was purged with nitrogen and charged with 4.0 grams of the above silica and 40 ml n-hexane thereby obtaining a slurry. This slurry was added with 1.5 ml hexane solution containing isobutylalumoxane (Tosoh Akzo Co., Ltd.) in a concentration of 1.0 mol/l of hexane and stirred at a temperature of 25°C for 30 minutes. At the end of this period, 0.5 ml hexane solution containing trimethyldiethylsiloxyalane synthesized in Inventive Example 1 in a concentration of 1.0 mol/l of hexane was added, followed by stirring at a temperature of 25°C for 30 minutes and removal of the solvent in vacuum. There was obtained a catalyst having a free fluidity property.

2) Polymerization

The procedure of Inventive Example 1 was followed thereby obtaining 10 grams of polyethylene. The resulting polyethylene was not well-balanced in rigidity and ESCR and lower in melt tension as compared to Inventive Examples 1 through 8.

Comparative Example 6

The procedure of Inventive Example 8 was followed except that 0.4 grams a Phillips catalyst comprising a silica supported with chromium trioxide (1.9 wt% of Cr) [969 MSB catalyst of W. R. Grace Corporation, which had been calcined at a temperature of 820°C for 18 hours] was substituted for the catalyst used for the invention comprising a chromium component, an alumoxane component, and an organometallic alkoxide and/or organoaluminum siloxide and the polymerization temperature was 100°C. There was obtained 150 grams polyethylene.

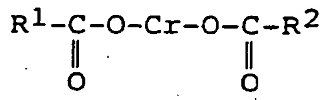
Table 1

	Mn x10-4	Mw x10-4	Mw/Mn	HLMFR	density	melt tension (g)	rigidity (kgf/cm^2)	ESCR (hr)
Inventive Example 1	1.51	25.6	17.0	4.8	0.9591	35.0	15500	52
" 2	1.52	25.5	16.8	4.6	0.9590	34.2	15500	50
" 3	1.45	26.9	18.6	4.9	0.9593	35.1	15700	54
" 4	1.42	26.0	18.3	4.6	0.9591	32.0	15400	48
" 5	1.43	25.8	18.0	4.5	0.9590	33.3	15200	50
" 6	1.50	25.8	17.2	4.6	0.9591	33.6	15400	52
" 7	1.47	26.1	17.8	4.7	0.9591	34.5	15300	58
" 8	1.49	26.0	17.4	4.4	0.9588	30.9	15600	56
Comparative Example 1	0.44	25.5	58.0	4.5	0.9574	26.0	13800	34
" 2	0.45	26.0	57.8	4.6	0.9574	25.2	13600	42
" 3	0.42	26.1	62.1	4.8	0.9576	26.1	13500	35
" 4	3.02	25.7	8.5	4.5	0.9553	24.8	13500	28
" 5	2.33	26.1	11.2	4.7	0.9562	27.2	14000	36
" 6	1.58	14.5	9.2	33.9	0.9590	11.0	13000	12

Claims

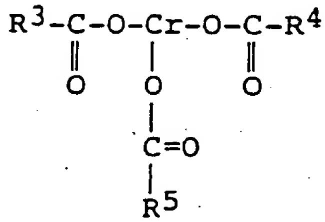
1. A process for the production of ethylenic polymers which comprises polymerizing an ethylenic monomer in the presence of a catalyst comprising a chromium component (a), an alumoxane component (b) and an organometallic component (c) supported on a carrier, said chromium component (a) being selected from the group consisting of

i) a chromium salt of carboxylic acid represented by either one of the the formulae



..... (1)

and

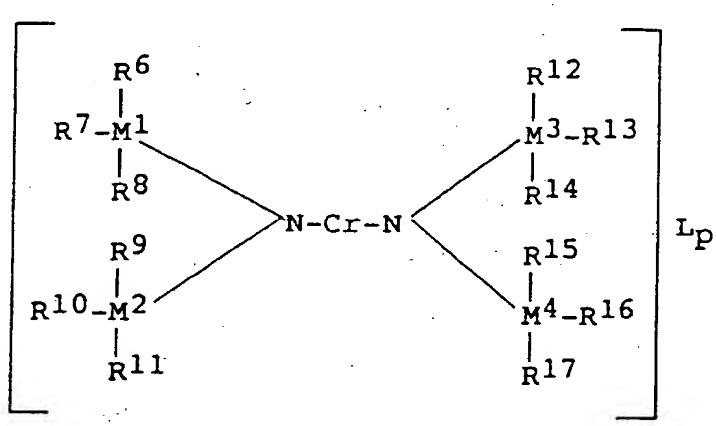


..... (2)

wherein R^1, R^2, R^3, R^4 and R^5 each are hydrogen or a C_1-C_{18} hydrocarbon group which may be the same or different,
ii) a chromium-1,3-diketo compound represented by the formula

$$CrX_kY_mZ_n \qquad (3)$$

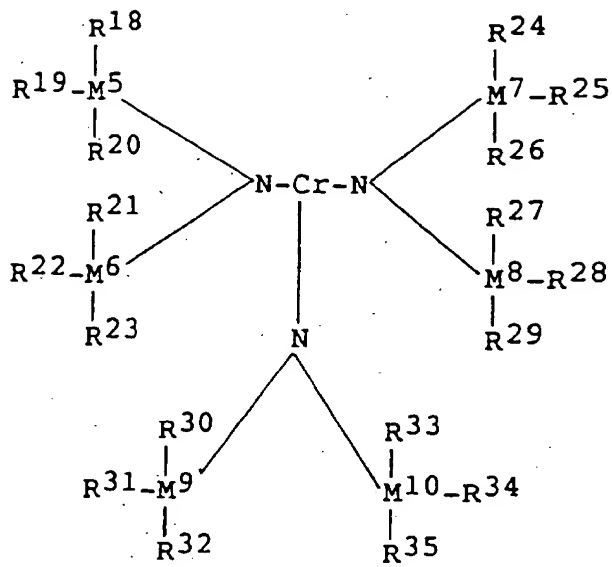
wherein X is a 1,3-diketo type chelate ligand, Y and Z are chosen from the group consisting of halogen, alkoxy, aryloxy, alkyl, aryl and amide, which may be the same or different, $k + m + n$ is equal to 3 and k is $1 \leq k \leq 3$, and
iii) a chromium amide compound represented by either one of the formulae



..... (4)

wherein R^6, R^7, R^8, R^9, R^{10}, R^{11}, R^{12}, R^{13}, R^{14}, R^{15}, R^{16} and R^{17} each are hydrogen or a C_1-C_{18} hydrocarbon group which may be the same or different, M^1, M^2, M^3 and M^4 are carbon and/or silicon, L is a ligand such as ether and nitryl and p is $0 \leq p \leq 2$

and



..... (5)

wherein R^{18}, R^{19}, R^{20}, R^{21}, R^{22}, R^{23}, R^{24}, R^{25}, R^{26}, R^{27}, R^{28}, R^{29}, R^{30}, R^{31}, R^{32}, R^{33}, R^{34} and R^{35} each are hydrogen or a C_1-C_{18} hydrocarbon group which may be the same or different and M^5, M^6, M^7, M^8, M^9 and M^{10} are atoms of carbon and/or silicon,

and said organometallic component (c) being selected from the group consisting of

i) an organoaluminum alkoxide represented by the formula

$$R^{45}{}_tAl(OR^{46})_{3-t} \quad (11)$$

where R^{45} and R^{46} are a C_1-C_{18} hydrocarbon group which may be the same or different and t is an integer of 1 or 2,

ii) an organoaluminum siloxide represented by the formula

$$R^{47}R^{48}R^{49}Si\text{-}O\text{-}AlR^{50}R^{51} \quad (12)$$

wherein R^{47}, R^{48}, R^{49}, R^{50} and R^{51} are a C_1-C_{18} hydrocarbon group which may be the same or different.

iii) an organomagnesium alkoxide represented by the formula

$$R^{52}Mg(OR^{53}) \quad (13)$$

wherein R^{52} and R^{53} are a C_1-C_{18} hydrocarbon group which may be the same or different,

iv) an organoboron alkoxide represented by the formula

$$R^{54}{}_uB(OR^{55})_{3-u} \quad (14)$$

wherein R^{54} and R^{55} are a C_1-C_{18} hydrocarbon group which may be the same or different and u is an integer of 1 or 2, and

2. A process according to claim 1 wherein said chromium component (a) is an ester of chromic acid represented by

the formula

$$\begin{array}{ccccccccc} & R^{36} & & O & & R^{39} & \\ & | & & \| & & | & \\ R^{37}- & M^{11} & -O- & Cr & -O- & M^{12} & -R^{40} \\ & | & & \| & & | & \\ & R^{38} & & O & & R^{41} & \end{array} \qquad \cdots\cdots \quad (6)$$

wherein R^{36}, R^{37}, R^{38}, R^{39}, R^{40} and R^{41} each are a C_1-C_{18} hydrocarbon group which may be the same or different and M^{11} and M^{12} each are a carbon atom or silicon atom,
and said organometallic component (c) is selected from the group consisting of said organomagnesium alkoxide and said organoboron alkoxide.

3. A process according to claim 1 wherein said catalyst is prepared by supporting on said carrier with said chromium component (a), said alumoxane component (b) and said organometallic component (c).

4. A process according to claim 1 wherein said catalyst is prepared by supporting on said catalyst with said chromium component (a), said organometallic component (c) and said alumoxane component (b).

5. A process according to claim 1 wherein said catalyst contains said chromium component (a) in the range of 0.05-5.0 percent by weight as the amount of Cr based on the weight of said carrier and has an atomic ratio of aluminum in said alumoxane component (b) to chromium in the chromium component (a) in the range of 0.5-100, an atomic ratio of B, Mg or Al in said organometallic component (c) to chromium in said chromium component (a) in the range of 0.5-100 and a molar ratio of said alumoxane component (b) to said organometallic component (c) in the range of 0.01-100.

6. A process according to claim 1 wherein said carrier is an inorganic metal oxide or an inorganic metal halide.

7. A process according to claim 6 wherein said carrier has a specific surface area of 50-1,000 m^2/g, a pore volume of 0.5-3.0 cm^3/g and an average particle size of 10-200 μm.

8. A process according to claim 1 wherein said alumoxane component (b) is an alkylalumoxane.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97850042.9

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 6)
X	EP - A - 0 364 290 (NIPPON OIL CO. LTD.) * Claims 1-7 *	1-6,8	C 08 F 4/602 C 08 F 4/78 C 08 F 4/22 C 08 F 10/02 C 08 F 4/02
X	EP - A - 0 237 294 (NIPPON OIL CO. LTD.) * Claim 1; page 3, lines 20-28 *	1,3,4, 6,8	
A	WO - A - 93/09 149 (CHEVRON RESEARCH AND TECHNOLOGY COMPANY) * Claims 1,6,7,9-22 *	1	
A	DE - A - 2 802 763 (HOECHST AG) * Claims 1-4 *	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.6)

C 08 F 4/00
C 08 F 10/00
C 08 F 110/00
C 08 F 210/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	09-06-1997	PUSTERER

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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& : member of the same patent family, corresponding document